Study of kappa distribution function with dust plasma particle densities on KAW instability in dusty plasma

Amar Singh Patneshwar[1], G.Ahirwar[2]

Student[1], Assistant Professor[2]

School of studies in physics, Vikram university, Ujjain (M.P.)-456010, India

Abstract : we have, present work on kinetic Alfven waves instability in dusty plasma. The expression for the particle densities, dispersion relation, growth rate and growth length of the kinetic Alfven waves are derived using the particle aspect analysis in auroral acceleration region. Our purpose in this paper is to be investigating the effect of kappa distribution function with dusty plasma on kinetic Alfven waves. The results of the work are consistent for Alfven wave in dusty plasma are applicable of the magnetospheric and astrophysical in auroral acceleration region.

***IndexTerms* – Kinetic Alfven wave, Dust plasma, Kappa distribution function**

1. INTRODUCTION

The kinetic Alfven wave is a low frequency electromagnetic wave and can propagate in the direction obliquely to the ambient magnetic field. Some evidences exist that Alfven wave also decolerate electrons above the auroral acceleration region along the magnetic field lines. When pressure effects become significant in electron and ion momentum equations the dispersion properties of the wave change significantly and such wave are called kinetic Alfven waves. The kinetic Alfven is the Alfven wave for which wave particle interaction is important. This wave has received much attention recently in connection with particle acceleration along the field lines[1-7]. Alfven waves play an important role in energy transport in driving field aligned currents particle acceleration and heating inverted-V structure in magnetosphere ionosphere coupling solar flares and the solar wind[8-9].The starting point of the model is the well know fact that in an auroral system the electric field perpendicular to the magnetic field reverses direction across a very narrow latitude range which is usually close to the edges of the auroral oval[10-11]. this region energetic ion tailward directed velocities and anisotropic ion distribution signatures are often observed[12-15]. particle aspect analysis that particle motion is considered not fluid to investigate the instability of kinetic Alfven waves in the magnetosphere .particle particle aspect analysis was firstly introduced by terashima[16]. study the instability of low frequency electrostatic drift waves in low β plasma[17]. kinetic Alfven waves in dusty plasma with external magnetic field[18]. studied low frequency kinetic Alfven waves in a dusty plasma using a fluid analysis which does not include landau damping[19]. considered kinetic Alfven wave analysis in a plasma with magnetized massive dust and have studied damping due to charge fluctuations[20]. investigated Alfven waves and other low frequency electromagnetic waves in non uniform dusty magnetoplasma. In addition to that low frequency long wavelength kinetic Alfven waves in multi beam dusty plasma with application to comment and planetary rings have been considered[21].effect of dust on Alfven wave absorption in tokomak edge plasma has been discussed[22-23]. these waves are ultra low frequency dust modes[24]. and are associated with the dust particle inertia. Here charged dust grains have a collective behaviour and take part in the wave dynamics magnetized dusty plasma support additional electrostatic low frequency waves involving the dynamics of magnetized unmagnetized dust grains and magnetized electrons ions[25-26].The Kappa model of ion exosphere[27]. used to study different plasma regions in the magnetosphere of the Earth[28]. Field aligned conductance values were also estimated from Maxwellian and Kappa distributions in quiet and disturbed events using Freja electron data[29]. Introducing a Kappa model appears to resolve discrepancy between calculations and observations of resonant plasma echoes and emissions used for in-situ measuring the local electron density and the magnetic field strength in the magnetospheric environments[30]. The three dimensional plasma sphere has been modeled using Kappa velocity distribution functions for the particles. this physical dynamic model of the plasma sphere gives the position of the plasma pause and the number density of the particles inside and outside the plasma sphere. The effects of super thermal particles on the temperature in the terrestrial plasma sphere were illustrated using

Kappa functions in[31]. The terrestrial polar wind is in some way similar to the escape of the solar wind: similar effects of super thermal particles appear and lead to an increase of the escaping flux[32]. Along open magnetic field lines, the wind speed is increased by the presence of super thermal particles. A Monte Carlo simulation developed the transformation of H polar wind velocity distributions with Kappa super thermal tails in the collisional transition region[33].

2. Basic trajectory

The kinetic Alfven wave is assumed to start at t=0 when the resonant particles are undisturbed. The main interest lies in the behaviour of kinetic Alfven waves, which satisfy the conditions.

$$V_{T\pi d}, V_{T\pi i} << \frac{\omega}{K_{\pi}} << V_{T\pi e};\ \omega << \Omega_i;\ \Omega_e, \Omega_d; K_{\perp}^2\rho_e^2 << K_{\perp}^2\rho_i^2; K_{\perp}^2\rho_d^2 < 1 \quad (1)$$

Where $V_{T\pi i}$, $V_{T\pi e}$ and $V_{T\pi d}$ are the mean velocities of ions, electrons and dust particles along the magnetic field, $\Omega_{i,e,d}$ are gyration cyclotron frequencies of the respective species. $K_{\perp}$ and K_{π} are the components of real wave vector k perpendicular and parallel to the magnetic field B_0. Consider the two particles representation of electric field a kinetic Alfven wave of the from (A K Dwivedi 2015)

$$E_{\perp} = -\nabla_{\perp}\phi \text{ and } E_{\Pi} = -\nabla_{\Pi}\psi$$

$$\overline{E} = \overline{E}_{\perp} + \overline{E}_{\pi}$$

$$\phi = \phi_1\cos(k_{\perp}x + k_{\pi}z - \omega t)$$

$$\psi = \psi_1\cos(k_{\perp}x + k_{\pi}z - \omega t) \quad (2)$$

where ϕ_1 and ψ_1 are assumed to be a slowly varying function of time t, and ω is the wave frequency which is assumed as real.$u_x(\bar{r},t)u_y(\bar{r},t)$ and $u_z(\bar{r},t)$ of the changed particles presence of KAW.

$$u_x(\vec{r}.t) = -\frac{q}{m}\left[\phi_1 k_{\perp} - \frac{V_{\pi}K_{\pi}K_{\perp}}{\omega}(\phi_1 - \psi_1)\right]\sum_{-\infty}^{+\infty}J_n(\alpha)\sum_{-\infty}^{+\infty}J_l(\alpha)\left[\frac{\Lambda_n}{a_n^2}cos\xi_{nl} - \frac{\delta}{2\Lambda_{n+1}}cos(\xi_{nl} - \Lambda_{n+l}t) - \frac{\delta}{2\Lambda_{n-1}}cos(\xi_{nl} - \Lambda_{n-l}t)\right]$$

$$u_y(\vec{r}.t) = -\frac{q}{m}\left[\phi_1 k_{\perp} - \frac{V_{\pi}K_{\pi}K_{\perp}}{\omega}(\phi_1 - \psi_1)\right]\sum_{-\infty}^{+\infty}J_n(\alpha)\sum_{-\infty}^{+\infty}J_l(\alpha)\left[\frac{\Omega}{a_n^2}sin\xi_{nl} - \frac{\delta}{2\Lambda_{n+1}}sin(\xi_{nl} - \Lambda_{n+l}t) - \frac{\delta}{2\Lambda_{n-1}}sin(\xi_{nl} - \Lambda_{n-l}t)\right]$$

$$u_z(\vec{r}.t) = -\frac{q}{m}\left[\psi_1 k_{\pi} - \frac{V_{\perp}K_{\pi}K_{\perp}}{\omega}(\phi_1 - \psi_1)\frac{n}{\alpha}\right]\sum_{-\infty}^{+\infty}J_n(\alpha)\sum_{-\infty}^{+\infty}J_l(\alpha)\frac{1}{\Lambda_n}[cos\xi_{nl} - \delta cos(\xi_{nl} - \Lambda_n t)] \quad (3)$$

Where δ=0 for non-resonant particles and δ=1 for resonant particle and

$$\Lambda_n = k_{\pi}v_{\pi} - \omega + n\Omega,\ a_n^2 = \Lambda_n^2 - \Omega^2$$

$$\alpha = \frac{k_{\perp}v_{\perp}}{\Omega},$$

$$\xi_{nl} = k_{\perp}x + k_{\pi}z - \omega t + (l-n)(\theta - \Omega t) \quad (4)$$

θ is the initial phase of the velocity and $\Omega = qB_0/mc$, u_x and u_y are the perturbed and velocities in the x and y direction respectively. The slowly varying quantities ϕ_1 and ψ_1 are treated as a constant.

Integration of eq. (3) gives the perturbed coordinates of particles x, y, z which in addition of trajectories of free gyration

Exhibits the true path of the particles. In the view of the approximations introduced in the beginning, the dominant contribution comes from the term n=0. J_s are Bessel's functions which arise from the different periodical variation of charged particles trajectories. The term represented by Bessel's functions show the reduction of the field intensities due to finite gyro radius effect.

In order to find out the Density perturbation associated with the velocity perturbation, $\vec{u}(\vec{r},t,\vec{v})$, we consider the equation for non-resonant particles

$$n_1(\vec{r}t) = F(\vec{v})\sum_{-\infty}^{+\infty} J_n(\alpha)\sum_{-\infty}^{+\infty} J_1(\alpha)\frac{q}{m}\left[\left\{\phi_1\frac{v_\Pi k_\Pi}{\omega}(\phi_1-\psi_1)\right\}\left\{\frac{k_\perp^2}{a_n^2}+\frac{\Omega^2 v_d k_\perp m}{\Lambda_n a_n^2 T_\perp}\right\}+\frac{k_\Pi^2}{\Lambda_n}\left\{\psi_1-\frac{n}{\alpha}\frac{v_\perp k_\perp}{\omega}(\phi_1-\psi_1)\right\}\right]\cos\xi_{nl}$$

(5)

The resonant particles we have.

$$n_1(\vec{r}t) = F(\vec{v})\sum_{-\infty}^{+\infty} J_n(\alpha)\sum_{-\infty}^{+\infty} J_1(\alpha)\frac{q}{m}\left[\left\{\phi_1\frac{v_\Pi k_\Pi}{\omega}(\phi_1-\psi_1)\right\}\left\{\frac{k_\perp^2}{a_n^2}+\frac{\Omega^2 v_d k_\perp m}{\Lambda_n a_n^2 T_\perp}\right\}\cos\xi_{nl}+\frac{1}{2\Omega\Lambda_{n+1}}\cos(\xi_{nl}-\Lambda_{n+1}t)\left(k_\perp^2-\frac{\Omega v_d k_\perp m}{T_\perp}\right)\frac{v_d k_\perp m}{\Lambda_n T_\perp}\cos(\xi_{nl}-\Lambda_n t)-\frac{1}{2\Omega\Lambda_{n+1}}\cos(\xi_{nl}-\Lambda_{n-1}t)\left(k_\perp^2+\frac{\Omega v_d k_\perp m}{T_\perp}\right)+\frac{k_\Pi^2}{\Lambda_n^2}\left\{\psi_1-\frac{n}{\alpha}\frac{v_\perp k_\perp}{\omega}(\phi_1\psi_1)\right\}\{\cos\xi_{nl}+\Lambda_n t\sin(\xi_{nl}-\Lambda_n t)-\cos(\xi_{nl}-\Lambda_n t)\}\right] \quad (6)$$

Where F(v) represent the kappa distribution function and V_d is the diamagnetic drift velocity which is defined by

$V_d = \frac{T_\perp}{m\Omega}\varepsilon_N; \varepsilon_n = \frac{1}{N}\frac{dN}{dy}$ homogeneous

To determine the dispersion relation and the growth rate, we use the by kappa distribution function with density perturbation.

3. Kappa distribution

$$N(y,v) = N_0\left[1-\varepsilon\left(y+\frac{V_x}{\Omega}\right)\right]f_\perp(v_\perp)f_\Pi(v_\Pi) \quad (7)$$

Where

$f_\perp(v_\perp) = \left[\frac{mv_\perp^2}{2K_B}\right]\frac{2k_\perp}{k_\Pi-1}$ $\quad f_\Pi(v_\Pi) = \left[\frac{mv_\Pi^2}{2K_B}\right]\frac{2k_\Pi}{2k_\Pi-1}$ and $\quad K = (k_\perp^2+k_\Pi^2)^{1/2}$

And ε is a small parameter of the order of inverse of the density gradient scale length.

4. Dispersion relation

To evaluated the dispersion relation, we calculate the integrated perturbed density for non-resonant particles as

$$n_{i,c,d} = \int_0^\infty 2\pi V_\perp\, dV_\perp \int_{-\infty}^\infty dV_\parallel n_i(r,t) \quad (8)$$

With the help of eq.(5) and (7) use find the average densities for homogeneous plasma as

$$\bar{n}_i = \frac{\omega_{pi}^2}{4\pi e}\left[\frac{-K_\perp^2\phi}{\Omega_i^2}+\frac{K_\parallel^2}{\omega_i^2}\psi\right](1-\frac{1}{2}k_\perp^2\rho_i^2)(\frac{2k-1}{2k}) \quad (9)$$

$$n_e = \frac{\omega_{pe}^2}{4\pi e V_{T\parallel e}^2}\psi \quad (10)$$

$$\bar{n}_d = \frac{\omega_{pd}^2}{4\pi Z_d e}\left[\frac{-k_\perp^2\phi}{\Omega_d^2}+\frac{k_\parallel^2\psi}{\omega^2}\right](1-\frac{1}{2}k_\perp^2\rho_d^2)(\frac{2k-1}{2k}) \quad (11)$$

It is observed that essential feature of the kinetic Alfven wave is retained even in this ideal case. For maxwell's equation we use the quasi-neutrality condition,

$$\bar{n}_i = \bar{n}_e + Z_d\bar{n}_d$$

We get relation between ψ and ϕ as:

$$\phi = \frac{\Omega_d^2}{k_\perp^2}\left[\frac{\omega_{pc}^2}{\omega_{pd}^2 v_{T\parallel}^2 A_2}-\frac{k_\parallel^2}{\omega^2}\left(1+\frac{A_1B_1}{A_2}\right)B_2^{-1}\psi\right.$$

(12)

Where

$A_1 = 1-\frac{1}{2}k_\perp^2\rho_i^2\left[\frac{2k_i-1}{2k_i}\right], \quad A_2 = 1-\frac{1}{2}k_\perp^2\rho_d^2\left[\frac{2k-1}{2k}\right]$

$B_1 = \frac{N_0}{N_{d0}}\frac{m_d}{m_i}\frac{1}{z_d^2}, \quad B_2 = 1-\frac{A_1B_1}{A_2}\frac{\Omega_d^2}{\Omega_i^2}$

Using perturbed ion, electron and dust particle densities n_i, n_e and n_d and Ampere's law in the parallel direction, we obtained the equation:

$$\frac{\partial}{\partial z}\nabla_\perp^2(\phi-\psi) = \frac{4\pi}{c^2}\frac{\partial}{\partial t}J_z \quad (13)$$

where

$$J_z = c\int_0^{\lambda} ds \int_0^{\infty} 2\pi V_\perp dV_\perp \int_{-\infty}^{\infty} dV_\parallel \frac{m_j}{2}[(N+n_1)(V+u)^2 - NV^2]_j$$

J_z is the current density which is contributed by first-order perturbations of density and velocity. we obtain the dispersion relation for the kinetic Alfven waves in homogeneous dusty plasma as:

$$\omega^4\left(\frac{\omega_{pe}^2 B_2}{k_\Pi^4\omega_{pd}^2 V_{T\Pi e}^4 V_A^2 A_2}\right) - \omega^2\left\{\begin{matrix}\frac{k_\perp^2 B_2}{k_\Pi^2\Omega_d^2}\left(1+\frac{\omega_{pd}^2 A_2}{c^2}\left(\frac{T_{\Pi d}}{m_d}\right)\right) + \frac{\omega_{pi}^2 A_1}{c^2 k_\Pi^2\Omega_d}\left(1-\frac{\omega_{pi}^2}{\omega_{pd}^2 V_{T\Pi e}^2\Omega_i^2 A_2}\frac{T_{\Pi i}}{m_i} - \frac{k_\perp^2}{\Omega_i^2}\frac{T_{\Pi i}}{m_i}\right) + \\ \left(\frac{\omega_{pe}^2}{c^2\Omega_d^2 V_{T\Pi e}^2 k_\Pi^2}\frac{T_{\Pi d}}{m_d}\right) + \left(\frac{B_2}{k_\Pi^2 V_A^2} - \frac{\omega_{pe}^2}{k_\Pi^2\omega_{pd}^2 V_{T\Pi e}^2 A_2}\right)\end{matrix}\right\} - \frac{\omega_{pi}^2}{c^2\Omega_i}\frac{T_{\Pi i}}{m_i}\left(1+\frac{A_1 B_1}{A_2}\right) -$$

$$\frac{\omega_{pd}^2 A_2}{c^2\Omega_d^2}\frac{T_{\Pi d}}{m_d} - \frac{A_1 B_1}{A_2} + 1 = 0 \qquad (14)$$

Where, $V_A^2 = \frac{c^2\Omega_i^2}{\omega_{pd}^2}$ is the square of Alfven's speed.

The oscillatory motion of non-resonant electrons carriers the major part of energy. The wave energy density per unit wave length W_w is the sum of pure field energy and the changes in energy of the non-resonant particles $W_{i,e,d}$. it is observed that the wave energy is contained in the from of the oscillatory motion of the non-resonant electrons.

5. Growth rate

using the low of conservation of energy, calculate the growth rate of drift kinetic Alfven wave by

$$\frac{d}{dt}(W_w + W_r) = \qquad (15)$$

With the help of we have found the growth rate of the drift kinetic Alfven wave with dusty plasma as:

$$\frac{\gamma}{\omega} = \frac{\pi^{1/2}\omega}{k_\parallel V_{T\parallel e}[1+\frac{\omega_{pi}^2 k_\parallel^2 T_\parallel A_1}{\omega^2\omega_{pe}^2 m_e} + \frac{\omega_{pd}^2 k_\parallel^2 T_\parallel A_2}{\omega^2\omega_{pe}^2 m_e}}\left(1+\frac{\omega^2}{k_\parallel^2 v_{T\parallel e}^2}\right)^{-(k+1)} \qquad (16)$$

6. Growth length

$$\gamma = \frac{\Gamma(\kappa+1)}{\kappa^{\frac{3}{2}}\times\Gamma\left(\kappa-\frac{1}{2}\right)} \times \left[\frac{\sqrt{\pi}\times\sqrt{\omega}}{K_\Pi . VT_{\Pi e} . \left[1+\frac{\omega_{pi}^2 . VT_{\Pi e}^2}{\omega.\omega_{pe}^2}.(A_x+P_x)\right]} . \left[1+\frac{\omega}{K_\Pi^2 . VT_{\Pi e}^2}\right]\right]^{-(\kappa+1)} \qquad (17)$$

$$V_p = \left[\frac{B}{\omega_{pd}^2 . VT_{\Pi e}^2 . V_a^2 . A_2} + \sqrt{B^2 + 4.\frac{\omega_{pe}^2 . B_2}{\omega_{pd}^2 . VT_{\Pi e}^2 . V_a^2 . A_2} . C . \frac{\omega_{pd}^2 . VT_{\Pi e}^2 . V_a^2 . A_2}{\omega_{pe}^2 . B_2}}\right]^{\frac{1}{2}} \qquad (18)$$

$$L_g = \frac{\left[\frac{B}{\omega_{pd}^2 . VT_{\Pi e}^2 . V_a^2 . A_2} + \sqrt{B^2+4.\frac{\omega_{pe}^2 . B_2}{\omega_{pd}^2 . VT_{\Pi e}^2 . V_a^2 . A_2} . C . \frac{\omega_{pd}^2 . VT_{\Pi e}^2 . V_a^2 . A_2}{\omega_{pe}^2 . B_2}}\right]^{\frac{1}{2}}}{\frac{\Gamma(\kappa+1)}{\kappa^{\frac{3}{2}}\times\Gamma\left(\kappa-\frac{1}{2}\right)}\times\left[\frac{\sqrt{\pi}\times\sqrt{\omega}}{K_\Pi . VT_{\Pi e} . \left[1+\frac{\omega_{pi}^2 . VT_{\Pi e}^2}{\omega.\omega_{pe}^2}.(A_x+P_x)\right]} . \left[1+\frac{\omega}{K_\Pi^2 . VT_{\Pi e}^2}\right]\right]^{-(\kappa+1)}} \qquad (19)$$

Where B and C are define as, and L_g is Growth length,

$$B = \frac{k_\perp^2 B_2}{k_\Pi^2\Omega_d^2}\left(1+\frac{\omega_{pd}^2 A_2}{c^2}\left(\frac{T_{\Pi d}}{m_d}\right)\right) + \frac{\omega_{pi}^2 A_1}{c^2 k_\Pi^2\Omega_d}\left(1-\frac{\omega_{pi}^2}{\omega_{pd}^2 V_{T\Pi e}^2\Omega_i^2 A_2}\frac{T_{\Pi i}}{m_i} - \frac{k_\perp^2}{\Omega_i^2}\frac{T_{\Pi i}}{m_i}\right) + \left(\frac{\omega_{pe}^2}{c^2\Omega_d^2 V_{T\Pi e}^2 k_\Pi^2}\frac{T_{\Pi d}}{m_d}\right) + \left(\frac{B_2}{k_\Pi^2 V_A^2} - \frac{\omega_{pe}^2}{k_\Pi^2\omega_{pd}^2 V_{T\Pi e}^2 A_2}\right)$$

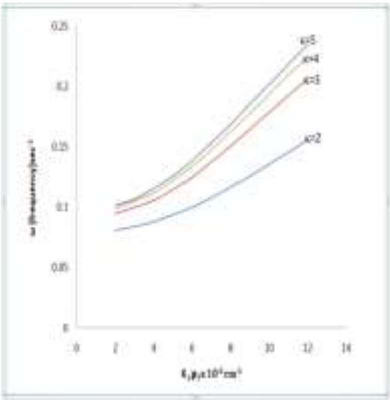
$$C = \frac{\omega_{pi}^2}{c^2\Omega_i}\frac{T_{\Pi i}}{m_i}\left(1+\frac{A_1 B_1}{A_2}\right) - \frac{\omega_{pd}^2 A_2}{c^2\Omega_d^2}\frac{T_{\Pi d}}{m_d} - \frac{A_1 B_1}{A_2} + 1$$

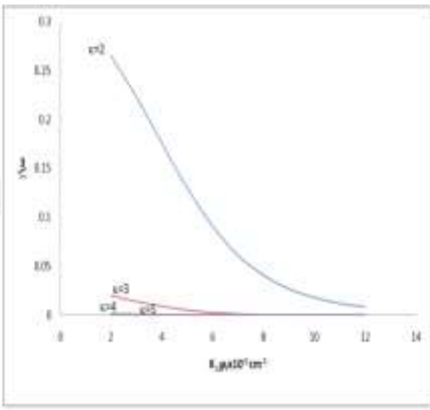
7. Results and discussion

The dispersion relation, growth rate and perpendicular wave for the kinetic Alfven wave in dusty magnetized plasma have been evaluated. The following dusty plasma parameters for the auroral acceleration region are used to calculate the dispersion relation, growth rate, (Shandilya et al., 2003,2004; Dwivedi et al., 2001; Das et al., 1996; Tiwari and Rostoker, 1984; Varma and Tiwari, 1992). The results are presented by fig. 1 to 6.

$\Omega_i = 412\ s^{-1}$; $\Omega_d = 6.88\times10^{-10}\ Z_d$; $m_d = 10^{-12} g$; $VT_{\Pi e} = 4\times 10^6 m\ s^{-1}$;

$KT_{\Pi i} = 1.6\times10^{-10}$; $N_d = 1\times10^6$;





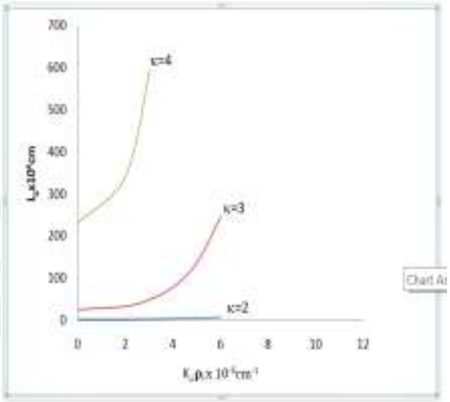


Fig.1 frequency (ω) versus Perpendicular wave ($k_\perp$)

Fig.2 Growth rate (γ/ω) versus Perpendicular wave ($k_\perp$)

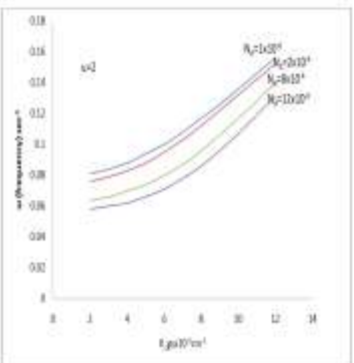
Fig.3 growth length (L_g) v/s Perpendicular wave ($k_\perp$)

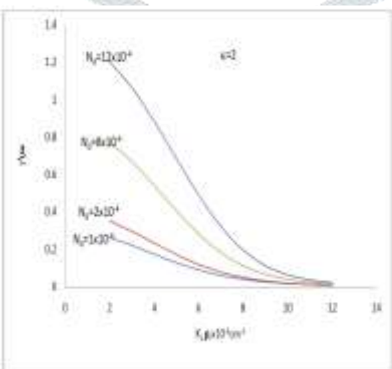
Fig.1 frequency (ω) versus perpendicular wave number ($k_\perp$) for different value of κ . it is found that the frequency (ω) is linearly increases with the increasing of the perpendicular wave number ($k_\perp$)cm^{-1} and the variation shows by straight line.

Fig.2 – Growth rate (γ/ω) versus perpendicular wave number ($k_\perp$) for different κ

Shows the relation between γ/ω with $k_\perp$ at different κ and fixed values of Z_d , N_d and m_d. it is found that the kappa inhomogeneity contributes to the wave growth. At the values of $k_\perp$ the wave growth is decreased. It is observed that kappa inhomogeneity is also a source of free energy to excite kinetic Alfven wave at the particular wave number.

Fig 3 show the variation of growth length (L_g) versus perpendicular wave vector ($k_\perp$) for different values of κ and fixed values of Z_d ,N_d and m_d. it is found that the growth length is increasing of the perpendicular wave number $k_\perp$.





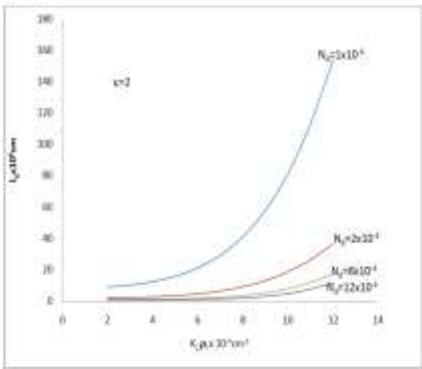


Fig.1 frequency (ω) versus Perpendicular wave ($k_\perp$)

Fig.2 Growth rate (γ/ω) versus Perpendicular wave ($k_\perp$)

Fig.3 growth length (L_g) v/s Perpendicular wave ($k_\perp$)

Fig.4 : frequency (ω) versus perpendicular wave number $k_\perp$ for different N_d .Exhibit the variation of wave frequency ω versus $k_\perp$ for different equilibrium dust number density N_d at the fixed values of dust grain Z_d and κ = 2. It is seen that the wave frequency is increases

Fig.5 : Growth rate γ/ω versus perpendicular wave number $k_\perp$ for different N_d .Shows the variation of growth rate γ/ω versus $k_\perp$ for different values of dust number density N_d at the fixed values of dust grain Z_d and κ=2. Here it is observed that the dust number density in homogeneity contributes to the wave growth .at the higher values of $k_\perp$ the wave growth is decreased.

Fig.6 : Growth length (L_g) versus perpendicular wave number ($k_\perp$) for different N_d.show the variation of growth length (L_g) versus perpendicular wave vector ($k_\perp$) for different values of N_d and fixed values of Z_d , and κ=2. it is found that the growth length is increasing of the perpendicular wave number $k_\perp$.

References

1. Eriksson PTI, Blomberg L G. Walker A DM & Glassmeier K -H. Ann Geophys, 23 (2005) 2679.
2. Sinha A K. Yeoman T K, Wild J A, Wright D M. Cowley S WH& Balogh A, Ann Geophys, 23 (2005) 919.
3. Schafer S, Glassmeier K H, ErikssonPTI, Pierrard V. Fornacon K H, & Blomberg L G. Ann Geophys, 25 (2007) 1011-1024.
4. Schafer S, Glassmeier K H. Eriksson PTI Mager P N. Pierrard V. Fornacon K H & Blomberg L G, Ann Geophys, 26 (2008) 1805.
5. Fenrich F R. Waters C L, Connors M & Bredeson C, Geophys Monograph Series, 169 (2006) 259.
6. Yeoman T K. Wright D M & Baddeley L J, Geophys Monograph Series, 169 (2006) 273.
7. Agarwal P & P Varma Indian Journal of Pure & Applied Physics 44(2011)
8. J R Wygant,2000 J. Geophys Res. 18 675
9. P Varma & Nidhi Shukla, Journal of Physics:Conference 208 (2010) 012034
10. Frank L A & Gurnett D A, J Geophys Res (USA),76 (1971) 5202.
11. Carlson CW &Kelly M C, J Geophys Res (USA), 82(1977) 2349.
12. Lui A T Y & Krimigis S M, Geophys Res Lett (USA), 10 (1983) 13.
13. Goertz C & lp W H, Geophys Ras Lett (USA), 11 (1984) 349.
14. Smith R A, Goertz C K & Grasmann W, Geophys Res Lett (USA), 13 (1986) 1380.
15. R P Shandilya & P Varma, Indian Journal of Radio & Space Physics 33 (2004).
16. Terashima, Y.,1967 Progr. Theoret. Phys. 37 (5).
17. Duan S P & Z Y Li Planetary and Space Science 53 (2005) 1167-1173.
18. N Ya Kotsarenko. S V Kushevaya andAN Kotsarenko Phys. Se ripta 56 388 (1996).
19. A C Das, A K Misra and K S Goswami Phys Rev E53 4 4051 (1996)
20. P K Shukla and H U Rahman Plunet Space Sei. 44 469 (1996)
21. R V Reddy. G S Lakhina, F Versheet and P Meuris Planet Space. Sei 44 129 (1996)
22. V S Tsypin. S V Vladımnov, A G Elfimov, M Tendler, A S de Assis and C A de Asevedo Phys Plamas 4 3436 (1997).
23. Shandilya R P,& P Varma Idian J. Phys.77B (5), (2003).
24. Rao, N. N.: Advances in dusty plasmas, edited by: Shukla, P K. Mendis, D. A., Desai, T., World Scientific, Singapore, 1996.
25. Rao, N. N., Shukla, P. K, and Yu, M. Y Dust-acoustic waves in dusty plasmas, Planet. Space Sci., 38, 543-546, 1990.
26. Jatenco V & A C L Chain, Nonlin. Processes Geophys., 21, 405-416, 2014.
27. Olsson. A. and Janhunen, P 1998, Ann Geoph. 16. 298
28. Picrrard, V. Khazanov, G. V., and Lemaire, J. 2007.
29. Picrrard, V and Lemaire, J 1996a, Geophys. Res. 101 7923
30. Vnas A F.,&Mace R L. 2005, J. Geophys.Res. 110, A06202.
31. Pierrard, V., and Lemaire, 1996b, Radiat. Meus. 26, 333.
32. Pierrard, V. Maksimovic, M. and Lemaire, J. F 2001, J Geophys. Res. 106, 29 305
33. Pierrard, V. and Stegen, K 2008, J Geophys. Res 113. A10209.